# RELATION OF CERTAIN FACTORS
# TO CURD VOLUME AND VISCOSITY
# OF COLOSTRUM FROM DAIRY COWS

by

EDWARD GRANT MOODY

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# INTRODUCTION

Colostrum differs from normal milk in many of its characteristics. In general, the constituents are more concentrated in colostrum than in normal milk. Apparently nature has provided this special material for the purpose of meeting the physiological demands of the neonatal calf.

Many investigators have reported wide variability in the colostral secretion and have also reported rapid changes from the first secretion to that of normal milk. Since the nutritive properties of colostrum from different cows varied widely and since colostrum was of considerable importance to the well-being of the calf, it would be desirable to have an index of the first secretion in terms of colostral properties. An attempt was made to determine whether the physical properties of creaming and viscosity might be used as a measure of the concentration of various nutrients, or the degree of colostral characteristics present; therefore, the composition of colostrum involving a number of constituents was determined for comparison with these two rather simple physical tests. Also, some factors which might influence the degree of the colostral characteristics of the postpartum secretion were studied to determine how the physical and chemical characteristics of this secretion might be affected.

## REVIEW OF LITERATURE

Little has been published regarding creaming and viscosity in colostrum, though these properties have been studied rather extensively in milk. Therefore, a review of the outstanding principles involved in these phenomena in milk will be beneficial to the study of creaming and viscosity of colostrum.

### Creaming in Normal Milk

The phenomenon of creaming in milk has been reported as due to a multiplicity of causes, primary among which was that of the clustering and rising of the fat globules. It was early recognized that creaming was closely associated with the fat content. Babcock (3), in 1889, postulated that the principal factor affecting the creaming of milk was the difference in specific gravity of the serum and the fat. Large fat globules and a small amount of solids-not-fat were favorable to creaming. More recently, Dunkley and Sommer (10) stated,

> The variable creaming properties of normal milks cannot be explained on the basis of differences in rates of rise of fat globules, the electrokinetic potential of the fat, nor the interfacial tension of the fat-serum interface, although each of these factors may play a specific part in the creaming process. Evidence concerning the importance of hydration of the adsorbed membrane on the fat globules was not sufficient to justify drawing a definite conclusion regarding the significance of this factor.

The results of their experiment showed that there is a remarkable similarity of the mechanisms involved in the agglutination of bacteria and the clustering of fat globules in milk, involving the presence of euglobulins.

Relative to cream layer depth in milk, Sommer (42) gave as the principal determinant the size and irregularity of fat clusters. Normally, he stated, there is a direct relationship between the cream volume and the fat content, the volume occupied by cream being 4.1 times the fat percentage after standing 24 hours.

The importance of the solids-not-fat to creaming was reported by Palmer and Anderson (32) who stated that the volume of cream rising on raw milk of uniform fat content is determined largely by the solids-not-fat in the plasma. They suggested further that neither size of fat globules nor their clumping determined the volume occupied by the risen fat. They refer to the work of Van Dam & Sirks showing that the addition of certain substances such as gum trogacanth, gelatin, starch, gum arabic, agar and saleb, increased the cream volume 15 to 25 per cent, concluding that it was the milk plasma and not the fat which has the chief influence on cream rising. The work of Rahn and of Hunziker, who stressed the importance of solids-not-fat in cream rising, was also referred to by Palmer and Anderson (32). Creaming, according to Dunkley and Sommer (10), will not take place in the absence of undenatured euglobulin. Hunziker (cited by 32) was of the opinion that the reduced cream volume in pasteurized milk was due to the coagulation of certain proteins. Orla-Jensen (30) reported that the cream volume of heated milk can be appreciably deepened by the addition of only one per cent of colostrum which is rich in globulin.

Peters and Trout (33) and Trout, et al. (45), suggested leucocytes as another factor possibly bearing a relationship to the depth of the cream layer. Due to a mutual attraction existing between fat globules and leucocytes, the two objects cohere, with the weight of the leucocytes tending to overcome the buoyancy of the fat globules. This, together with the increased volume due to the cells, resulted in an extended cream layer.

It would appear from the foregoing investigations that creaming involves not only the presence of butterfat but also the relationship of the solids-not-fat, especially the globulin fraction, and the cellular content as well.

A relationship between cream volume and viscosity in milk was reported by Palmer and Anderson (32) who further concluded that the viscosity of raw milk was a good index of its creaming ability and could be used as an explanation of changes in cream layers caused by the temperature of creaming or the concentration of plasma solids in the milk.

## Viscosity in Normal Milk

The factors affecting the viscosity of milk and cream were first studied, according to Dahlberg and Hening (8), by Soxhlet in 1876. In subsequent studies various instruments were used to measure viscosity: Dahlberg and Hening (8) used the MacMichael viscometer; Whitaker, Sherman and Sharp (47) used the Ostwald viscometer; Bateman and Sharp (4) used the Bingham viscometer; Babcock (2) used the Saybolt viscometer; and Nair and Mook (29), Hening (21), and Skelton and Herreid (40) used the Borden Body Flow Meter.

Viscosity in milk was affected by the individuality, ration, period of pregnancy and lactation, and the health of the cow (8). Viscosity of cream was not greatly influenced by the transition from summer to winter conditions (40), but it did show a day to day variation regardless of how it was handled (21). The variability of viscosity of milk and cream was also reported by Dahlberg and Hening (8).

The viscosity in milk was related directly to the total solids content (8, 32), though it is not a strictly linear function and does not accurately indicate the total solids content (4). Some investigators tend to believe fat to be the most important cause of viscosity and any factors affecting the fat percentage and clumping of fat globules will have an effect on viscosity. Thus, it is believed that it is the effect of increased temperature, pasteurization and mechanical agitation upon the clumping of fat globules that causes the decreased viscosity; furthermore, the greater viscosity noted in milk and cream after aging for 48 hours is due to the clumping of fat globules that has occurred (2, 4, 8).

On the other hand, it was the conclusions of Palmer and Anderson (32) that most of the specific viscosity of milk was due to the solids-not-fat. Casein, according to Kabler (reported by Palmer and Anderson (32), greatly influenced the viscosity. Whitaker, et al. (47), concluded that the effect of lactose on this property was small when compared with the proteins.

There appears to be no general agreement as to the fundamental cause of viscosity, but it is apparent from these data that several factors such as the condition of the cow, together with treatment and milk solids of the sample are involved in determining the viscosity in milk and cream.

## Creaming and Viscosity in Colostrum

Relative to the property of creaming in colostrum, Fleishmann (17) noted that two layers would often form on the undisturbed secretion. Hills (22) observed that the cream layer thus formed was deeper than it was in the milk secreted three weeks later. This increased creaming ability was, according to Houdiniere (24), due to the increased content of albumin, globulin and soluble phosphate found in colostrum.

That colostrum was "slimy" or "viscous" has been noted by almost all authors who have attempted a description of this secretion, but apparently none have attempted a further study. An explanation for these noted increases in the creaming and viscosity has been sought in a study of the composition of colostrum.

## Composition of Colostrum

A great number of investigators have studied the composition of colostrum, although not all agree on the relative amounts of the constituents. Engel and Schlag (13) found the average fat percentage of colostrum to vary between 2.8 and 6.9 per cent showing no distinct pattern, whereas Jacobson and Wallis (25) showed a mean fat percentage of about four per cent for the first 15 days. The Associates of Rogers (1) and Richmond (36) in reviewing the work of others noted different amounts reported. None, however, reported a lower fat content than 1.36 per cent or higher than 7.40 per cent which would indicate that the fat content would not play a major part in the extreme creaming and viscosity that is often noted in colostrum.

Of the solids-not-fat, the proteins (especially globulin) were the most important constituent quantitatively. Often, in determinations of protein content, the albumin and globulin are calculated as one fraction. Crowther and Raistrick (7) gave the following analyses of colostrum proteins: total protein 18 to 20 per cent, caseinogen 4 to 5 per cent, albumin 0.7 to 1.5 per cent, globulin 6 to 12 per cent. Others (1, 7, 11, 13, 14, 20, 22, 30, 36, 43) have reported a globulin content of from 5.77 to 36.86 per cent. Wise and Parrish (50) gave the protein analyses as indicated below:

> first milking postpartum, casein 6.4 per cent, albumin and globulin 10.1 per cent; fourth milking postpartum, casein 3.4 per cent, albumin and globulin 1.3 per cent;

> fourth day composite, casein 3.2 per cent, albumin and globulin 0.72 per cent; fourteenth day composite, casein 2.6 per cent, albumin and globulin 0.57 per cent.

It is of interest to note that the most radical changes in protein composition have taken place by the time the udder is emptied for the fourth time which would strongly suggest that they are largely responsible for the colostral properties and play an important part in the creaming and viscosity of colostrum.

The reported ash content was usually slightly higher whereas the lactose content was slightly lower in colostrum than in normal milk, which difference would not suggest an appreciable effect upon the creaming and viscosity. Ross (37) reported that the colostral leucocyte content is over 50 times that of normal milk while others (6, 24, 34) have similarly reported the presence of large numbers of cells which might play a minor role in the colostral creaming and viscosity.

Other workers (15, 17, 24, 26, 31, 46) have also reported analyses of the composition of colostrum.

## Variability of Colostrum

In the study of the composition of colostrum it was noted that variation existed to a greater or lesser degree in all constituents studied. Such variability has been recognized by many authors (1, 13, 25) and is given by Hollen (23) as a chief cause for the contradictory results of the experiments conducted on this product.

The variability in the mammary secretion was reported as being related to:

(a) length of time cow was dry (11);

(b) breed (12);

(c) individuality (12, 31);

(d) feed (12) (Only effect of feed is through its influence on the daily volume (28, 44) );

(e) interval between milkings (12) (Hammond (20) states that more frequent milkings increase the rate of transition from colostrum to normal milk. This view is questioned by Overman and Sanmann (31) );

(f) health of animal (12);

(g) temperature and weather conditions (13);

(h) age or number of lactation (Ernst (16) stated that heifers showed more colostral properties than older cows);

(i) stage of lactation (The length of time in active lactation since calving influences the composition of the secretion, especially the first few days postpartum (7, 16, 17, 20, 22, 23, 25, 31, 43, 51). The observations of these investigators indicate that there is a marked tendency for the mammary secretions to become normal in the first four days postpartum. According to Engel and Schlag (13), the colostral period extends up to the twelfth day and can be determined absolutely by the globulin content.); and

(j) edematous condition of udder (48).

From these data, it was concluded that the creaming and viscosity of colostrum are influenced by a large number of fluctuating factors. This may be partially responsible for the great variability noted in the colostral product.

## EXPERIMENTAL PROCEDURE

In order to further study the relation of certain factors to the creaming and viscosity of colostrum, the following procedure was outlined.

### Collection of Data

Data included in this study were collected during the years of 1945 to 1947 coincident with other investigations underway with the Kansas State College purebred dairy herd. The 123 cows were classified according to breed, number of lactation and ration as indicated in Table 1.

Table 1. Number and breed of cows used.

| Breed | No. lactation | | Ration | | Total |
|---|---|---|---|---|---|
| | First | Later | Pasture | Winter | |
| Holstein | 15 | 22 | 17 | 20 | 37 |
| Ayrshire | 13 | 15 | 11 | 17 | 28 |
| Jersey | 21 | 17 | 21 | 17 | 38 |
| Guernsey | 10 | 10 | 4 | 16 | 20 |
| Total | | | | | 123 |

As a basis of classification, cows beginning lactation for the first time were classified as first lactation animals and those in the second to seventh lactations were classified as cows in later lactations.

In order to study the effect of feed, cows were classified as to whether they received fresh green feed in their prepartal ration. The pasture was of various types, sometimes constituting the entire feed intake, but often supplemented with grain mix, alfalfa hay and silage; whereas the winter ration consisted only of grain mix, alfalfa hay and silage sometimes supplemented with a vitamin concentrate (being fed for another experiment). This ration was fed to the cow for at least four weeks prepartal. During the experimental period all cows received standard herd treatment.

Information concerning the time of parturition, length of the dry rest period, and the length of the gestation period was collected. Observations were made of the experimental animals several times weekly both before and after parturition. The severity and extent of mammary edema were estimated by palpation and visual observation. From this information the cows were classified within one of four groups on the basis of the severity of edema.

The mastitic condition at the time of parturition was determined by the Department of Bacteriology of the Kansas State College from the results of a microscopic examination (27) of the mammary secretion prior to its use for human consumption.

Cows entirely free from any mastitic condition were classified "A", cows suspected by reason of their high (over 500,000/ml.) leucocytes present were classified "B", and cows definitely mastitic as shown by the presence of long-chain streptococci and staphylococci were classified "C".

In order to obtain the complete colostral secretion for analysis, the new-born calves were prevented from suckling and the dams' udders were milked out completely twice daily, the first milking taking place two to six hours postpartum. The amount of colostrum withdrawn was recorded and representative samples were collected from each milking on the first, second, third, fourth and seventh days. The samples were stored at 40° to 50° F. for 24 hours whereupon each sample was uniformly mixed and cream volume was determined by placing 200 cc. in a graduated cylinder to be held at 50° F. for 48 hours, at the end of which time the cream volume was measured.

After setting aside the sample for cream volume determination, the viscosity was determined by placing 200 cc. in a Borden Body Flow Meter (29) and the time required for the efflux of 188 cc. (12 cc. remained in the jar) through a 1.97 mm. orifice at 50° F. was recorded in seconds and expressed as the rate of flow.

Macroscopic examination for a brown or red color was made to determine the presence or absence of blood. When a sufficient number of samples had been collected, requiring approximately a week's time, the fat content was determined by the Babcock Method.

The following analyses were made on the individual samples of colostrum from the first six milkings and on daily composites from the secretion on the fourth and seventh days. These samples were stored at 4° C. until analyses could be made. The analyses, listed with their method of determination, of the following properties were made in order that their relationship to creaming and viscosity could be learned:

(a) specific gravity, determined with the Westphal balance at 20°/4° C.;

(b) solids-not-fat, determined by calculation;

(c) protein constituents, determined by an adaption of procedure used by Rowland (38);

(d) lactose, determined by use of the method outlined by Garrison and Haigh (18);

(e) ash, determined by evaporating a sample to dryness and heating in a muffle furnace overnight at 500° C.;

(f) carotenoids and vitamin A, determined by an adaption of Boyer, et al. (5), described briefly by Wise, et al. (49); and

(g) vitamin E which was determined by a modification of Quaife's method (35).

These above methods were used because they were the best known means of obtaining comparative analyses with a minimum of time and expense.

The number of leucocytes in the colostrum from 13 cows was determined in the first, third and eighth milkings. Breed's microscopic method (27) was followed making use of Pappenheim's stain (19) which facilitated the differentiation of cells.

## Treatment of Data

After they had been collected and classified, data were plotted in scatter diagrams which would show the relation of cream volume and rate of flow to each other, to season, length of dry rest and gestation periods, edema and mastitis, amount of colostrum secreted, specific gravity, fat percentage and carotenoid and vitamin A content. In preliminary studies, diagrams showing these relationships were prepared for each breed, the lactation and ration being listed separately in order to present a more complete picture of the association. Although scatter diagrams were made for all breeds, generally only data from the Jersey breed was used in this presentation. Justification for this choice is to be found in Table 1 which shows the more balanced condition of this breed both in lactation and ration as well as a larger total number. In addition to this, there was little significant differences noted between breeds.

The relation of cream volume and rate of flow to solids-not-fat, total protein, albumin and globulin, casein, lactose and ash were plotted according to the lactation and ration only, while in the case of vitamin E comparison was made only on a basis of whether or not a vitamin E supplement had been fed. The leucocyte counts were compared to cream volume and viscosity without distinguishing between any other factors. For these determinations only the analyses of the colostrum from the first milking was used because preliminary studies had indicated that the first secretion displayed the most marked colostral characteristics. After preparing these scatter diagrams, the product-moment coefficients (41) were calculated where a possible linear correlation was indicated.

The data pertaining to the transition, breed, ration, season of year, number of lactation, severity of edema, mastitic condition and the presence of blood as they were related to creaming and viscosity were studied by calculating the average cream volume and rate of flow for each group and when applicable, testing the significance by analysis of variance or the t-test (41).

## EXPERIMENTAL RESULTS

There are many more or less complex analyses requiring considerable amounts of skill, time and equipment that would indicate the colostral properties of a secretion. Since it is not always practicable to make such analyses, a simple test or tests that would be indicative of the colostral properties would be highly desirable. As the cream volume and rate of flow seemed to meet these requirements, they were selected as a basis of comparison in this study. Before determining the relation of these factors, however, it was deemed advisable to study the creaming and viscosity in light of the transition from colostrum to normal milk and some of the conditions which might have an influence upon their expression.

## Transition from Colostrum to Normal Milk

The findings of other investigators to the effect that a rapid change took place in the mammary secretion for the first few days postpartum were substantiated by these experimental results. The cream volume and relative viscosity (expressed as rate of flow) were used to measure the transition of the mammary secretion from colostrum to normal milk. The degree of creaming and viscosity were determined the first four days on each sample drawn and again on the seventh day. This transition is shown in the over all cream volume and rate of flow values of Table 3. Since in all breeds studied the trend was the same as shown in Fig. 1, it was concluded that the breed had no effect on this transition. The greatest cream volume and viscosity occurred in the first colostrum drawn, thereafter the extent of these properties decreased rapidly through the third milking and leveled off to the eighth milking. From this point, the average cream volume remained rather constant whereas the average rate of flow continued to decrease slightly. The radical changes in colostral properties which take place during the first few milkings postpartum are illustrated in Plate I, which shows the transition in cream volume occurring in the colostral secretions of Jersey cow 352A.

Although it was found in most cases that cream volume and viscosity were greatest in the first colostrum drawn and decreased subsequently, among 123 samples, there were 28 exceptions in which cream volume was greatest in any milking other than the first, and two in which the rate of flow followed the same pattern. For these 28 cows the average cream volume and rate of flow values during the first 48 hours are shown in Table 2 where it was demonstrated that in the third and fourth milkings these properties are the same as the over all average.

Table 2. Average cream volume and rate of flow of colostrum showing a greater cream volume in any milking other than the first.

| Days | Milking | Cream volume (per cent) | Rate of flow (seconds) |
|---|---|---|---|
| 1 | 1 | 27 | 166 |
|  | 2 | 42 | 95 |
| 2 | 3 | 21 | 63 |
|  | 4 | 20 | 56 |

The transition to normal milk was more rapid in the rate of flow than in the cream volume. Although Fig. 1 shows a slight breed difference in the rate of change from colostrum to normal milk, there was little basis for the assumption that breed plays an important part in the transition to normal milk.

Under the conditions of this experiment where cows were milked out twice daily, the term colostrum has been applied to all secretion up to the eighth milking postpartum, although marked colostral properties do not persist beyond the third or fourth milking. For dairymen this allows a certain margin of

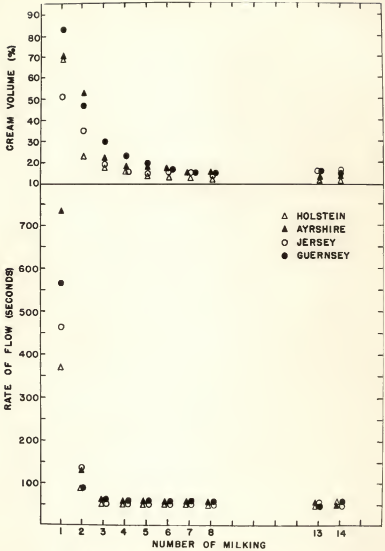
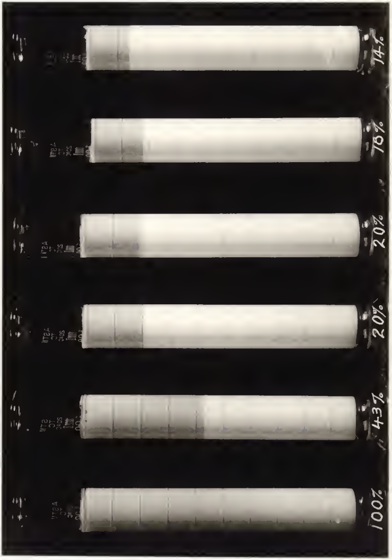


FIG. I. TRANSITION OF COLOSTRAL CREAM VOLUME AND RATE OF FLOW BY BREEDS.

## EXPLANATION OF PLATE I

The creaming of colostrum from Jersey cow, 352A (Two cc. saturated alcoholic solution of Sudan III added to each 100 cc. colostrum for photographic purposes).

PLATE I



safety in the elapse of the customary four days postpartum before the milk is considered marketable. Some authors state that a longer period of time is required for the milk to become "normal" in all respects, but with the possible exception of a few cows, the properties studied herein have for all practical purposes reached "normal" levels after the eighth milking. The judgment of the producer in applying the rule to the individual cow is important.

## Variation in Cream Volume and Viscosity

According to the data presented in Table 3 and Figs. 2 through 12, variation between the creaming and viscosity of different samples of colostrum was greatest in the first milking postpartum, after which the difference between the highest and lowest values became successively smaller. It was observed that the individual cow ordinarily did not persistently secrete colostrum with either extremely high or low creaming or viscosity, but rather a secretion with extreme properties was generally followed by colostrum with cream volume or rate of flow nearer the average for the group.

The tendency of the variability to be greatest in the first secretions and become less variable in later secretions followed the same general trend as the transition from colostrum to normal milk, suggesting that it is those factors causing high creaming and viscosity that fluctuate to the greatest extent.

Table 3. Variation between cream volume and rate of flow of individual samples of colostrum.

| | Milking postpartum | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 13 | 14 |
| Cream volume (per cent) | | | | | | | | | | |
| highest | 100 | 98 | $65^1$ | $89^1$ | $53^1$ | $52^4$ | $34^4$ | $31^4$ | $24^2$ | $24^2$ |
| lowest | 3 | 8 | 6 | 8 | 8 | 5 | 5 | 4 | 7 | 9 |
| average | 66 | 40 | 21 | 18 | 16 | 16 | 14 | 14 | 14 | 14 |
| Rate of flow (seconds) | | | | | | | | | | |
| highest | 4410 | 788 | 179 | 81 | $120^1$ | $114^1$ | $65^3$ | 67 | $64^3$ | $64^3$ |
| lowest | 53 | $49^5$ | $46^5$ | $47^5$ | $47^5$ | $47^5$ | $48^5$ | $48^5$ | 45 | 46 |
| average | 514 | 115 | 101 | 56 | 55 | 54 | 53 | 53 | 51 | 51 |

1, 2, 3, 4, 5, indicate values from the same cow.

Representatives of all four breeds were to be found in both the highest and lowest values during the colostral period of four days, indicating little, if any, influence of breed upon the wide variability.

## Effect of Certain Factors Upon Creaming and Viscosity

As a basis of comparison it was necessary to make uniform use of the analyses from one of the milkings which showed colostral properties. For this purpose, the first colostrum drawn from the udder was used because, as shown in Fig. 1, the cream volume and rate of flow as well as other properties were then most "colostral" in nature.

As a further indication that any relationships present would be found to the greatest degree in the first colostrum drawn was the observation based on preliminary studies that the apparent effect of the factors of breed, ration and lactation disappear rapidly with the transition to normal milk after the third milking, thereafter acquiring properties characteristic of the different breeds. Also, at the first milking the physical condition of the cow was most similar to that at time of parturition, making a more uniform basis of study.

Effect of Breed on Creaming and Viscosity. It will be noted from Fig. 1 that after the third milking the breed differences were no longer apparent, and during this period the differences were not consistent and the order not the same for cream volume as it was for rate of flow. For the first milking Guernsey colostrum had the highest cream volume, followed by the Ayrshire, Holstein and Jersey; while for the rate of flow, the Ayrshire colostrum had the greatest value followed by the Guernsey, Jersey and Holstein colostrum. The top and bottom pair were the same in both cases, however.

Data in Table 4 further indicated the variability of the colostral product. When studied statistically, the difference existing in cream volume between the colostrum from Holstein and Ayrshire breeds was nonsignificant, being very nearly the same. Likewise, the difference between the Guernsey and Holstein or Ayrshire breeds was nonsignificant. The difference between Jersey and Ayrshire or Holstein colostrum, however, was found to be significant while that between the Jersey and Guernsey colostrum was highly significant. The validity of the greater amount of creaming which was noted in the colostrum from Guernsey cows shown in Fig. 1 is questioned by the data of Table 1 which show that there were 4 times as many Guernsey cows on winter ration as on pasture, leading to the conclusion that the difference was not entirely due to the breed.

The differences between the rate of flow values for the different breeds was found to be nonsignificant due to the wide variability within each breed. However, when comparing the colostrum from the later lactations of Holstein and Ayrshire cows, a significant difference was demonstrated which can be traced to the low variability of the colostrum from the Holstein

Table 4. The effect of breed and lactation upon the cream volume and viscosity of colostrum.

| Breed | Lactation | Number animals | Mean and standard error: Cream volume (per cent) | Mean and standard error: Rate of flow (seconds) |
|---|---|---|---|---|
| Holstein | first | 15 | 71.2 ± 8.2 | 623 ± 288 |
| | later | 22 | 64.9 ± 6.4 | 212 ± 34 |
| Ayrshire | first | 13 | 63.7 ± 8.4 | 817 ± 400 |
| | later | 15 | 76.2 ± 8.3 | 623 ± 167 |
| Jersey | first | 21 | 55.9 ± 7.7 | 489 ± 123 |
| | later | 17 | 35.0 ± 8.6 | 433 ± 139 |
| Guernsey | first | 10 | 83.0 ± 8.0 | 730 ± 579 |
| | later | 10 | 82.7 ± 6.3 | 402 ± 98 |

cows. A greater viscosity was shown by the Ayrshire cows in the first milking, but this rank is lost to the Jersey breed in the second milking, strongly suggesting that the difference was due not to the breeds involved but rather to the extremely viscous colostrum secreted by a few Ayrshire cows in the first milking.

The conclusion drawn from these data is that although the creaming and viscosity in normal milk are generally recognized as being greater in the Channel Island breeds, this characteristic does not apply in colostrum, for no significant differences due to breed was noted during the colostral period of four days.

*Effect of Numbers of Lactations Upon Creaming and Viscosity.* After noting no significant breed differences in the creaming and viscosity of colostrum, the possible effect of the numbers of lactations within each breed upon these properties was studied. It was found that cream volume was higher in colostrum from first lactation Holstein, Jersey and Guernsey cattle than in colostrum from later lactations of these same breeds. However, in the Ayrshire breed, the mature cows had the higher values in first milking colostrum only. The viscosity, on the other hand, in all cases was higher in the colostrum from heifers than mature cows, Table 4. Although these differences between the first and later lactations within each breed when tested statistically proved to be nonsignificant due to the variability within each group, it is notable that with the one exception indicated, the values were greater in colostrum from cows lactating for the first time. This would strongly suggest that the lactation played a more important part in determining the extent of creaming and viscosity of colostrum than was indicated by the statistical analyses. A possible explanation for this inference is that the mammary tissue in beginning to function for the first time may have a greater accumulation of proteins, lymphoid and other fluids as a result of growth and development, which substances might be responsible for some of the noted colostral properties.

Effect of Ration Upon Creaming and Viscosity. For the purpose of determining the effect of pasture upon colostral creaming and viscosity, data were arranged according to whether the cow had received pasture in the prepartal ration. Results showing this effect in the first postpartal milking are presented in Table 5.

Table 5. The effect of ration on colostral cream volume and rate of flow.

| Lactation group | Ration | No. cows | Cream volume (per cent) | Rate of flow (seconds) |
|---|---|---|---|---|
| First | Pasture | 26 | 58 | 385 |
| | Winter | 17 | 64 | 550 |
| Later | Pasture | 23 | 48 | 285 |
| | Winter | 11 | 78 | 299 |
| Both groups | Pasture | 49 | 53 | 338 |
| | Winter | 28 | 69 | 451 |

Since there was no pasture from December to March, cows freshening in this period were not included, thus minimizing the effect of the season upon the results. It was found that all values were lower in colostrum from animals that had been on pasture. When the differences were tested by analysis of variance, the difference of 16 per cent cream volume was significant (P, less than 0.05) but that of 113 seconds in the rate of flow was not statistically significant (P, greater than 0.50). This tendency for a lower cream volume and rate of flow in colostrum from animals that had been on pasture is further illustrated in Figs. 2 through 12.

*Effect of Season on Creaming and Viscosity.* After finding that the ration seemed to influence the composition of colostrum, the possible effect of the temperature was studied. Table 6 consists of average cream volume and viscosity values in the first milking colostrum from all cows receiving a winter ration throughout the year; colostrum analyses from cows receiving fresh feed prior to parturition were not included in order to eliminate the possible effect of the ration.

Since the samples of colostrum included in this group were from cows not comparable as to breed, lactation and/or certain other factors, these findings did not lend themselves to a statistical analysis. Never-the-less, there was apparently a seasonal difference, the values tending to become lower in the summer and higher in the winter months.

Table 6. Effect of season upon colostral cream volume and rate of flow.

| Season | Lactation | No. cows | Cream volume (per cent) | Rate of flow (seconds) |
|---|---|---|---|---|
| Winter | first | 15 | 85 | 1071 |
| | later | 23 | 75 | 553 |
| | all lactations | 38 | 80 | 757 |
| Spring | all lactations | 18 | 73 | 478 |
| Summer | all lactations | 6 | 52 | 107 |
| Fall | all lactations | 9 | 80 | 663 |

Figure 2 shows the distribution throughout the year of colostral cream volume and rate of flow from Jersey cows classified according to different feeding regimes and numbers of lactations involved. While showing the wide variability of creaming and viscosity of colostrum, the tendency for colostrum secreted during the hot summer months appeared to be lower in cream volume and viscosity than that colostrum secreted during the winter months.

Effect of Length of Dry Period Upon Creaming and Viscosity. It was the observation of Eckles and Palmer (11) that the composition of colostrum was influenced by the length of the dry period. In order to test this effect upon colostral cream volume and rate of flow, scatter diagrams were constructed for all breeds to determine if any relationship existed between these

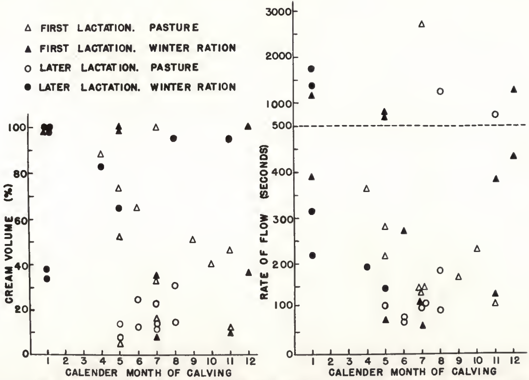


FIG. 2. EFFECT OF SEASON, LACTATION, AND RATION UPON COLOSTRAL CREAM VOLUME AND RATE OF FLOW IN JERSEY COWS.

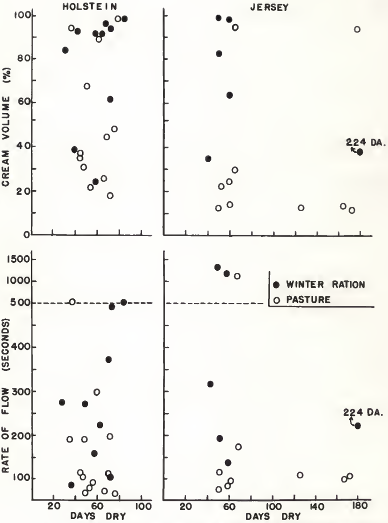


FIG. 3. EFFECT OF DRY REST PERIOD ON CREAM VOLUME AND RATE OF FLOW IN COLOSTRUM FROM HOLSTEIN AND JERSEY COWS.

factors. In Fig. 3 data are presented showing the effect in Holstein and Jersey breeds, indicating that there is no relationship present in animals having rest periods of 29 to 224 days (averaging about 60 days). Although wide variation was noted, there was no general trend for a higher cream volume or rate of flow as the dry period was extended. The same was true of the other two breeds.

The effect upon the properties of the mammary secretion when there is no dry period is indicated in the results obtained from a Holstein cow (126A) milked continuously from the first parturition to the second. Her colostral secretion was without color and had a lipolytic odor and a tendency to foam which persisted until the fourth postpartal milking. The cream line was not definite but was estimated to be at the two per cent level for several days immediately prior to parturition and during the first day following parturition. The fat content, meanwhile, was six to eight per cent. The cream volume had increased to 14 per cent by the eighth milking followed by a decrease to 12 per cent in the fourteenth milking, by which time the cream line had become definite. The rate of flow for the milking just prior to parturition was 81 seconds and for the first milking postpartum the rate of flow was 100 seconds after which it decreased steadily to 55 seconds in the fourteenth milking.

These foregoing results would indicate that if there is a dry period of at least a month the colostral secretion will be "normal", but if there is no dry period such colostral properties do not develop.

*Effect of Length of Gestation Upon Creaming and Viscosity.* The possible effect that the length of gestation might have upon the colostral cream volume and rate of flow was studied according to breeds by means of scatter diagrams. These showed no relationship between cream volume and rate of flow when cows calved normally between 247 and 296 days; however, the colostrum from two heifers, 130A and 373A, which aborted after 220 and 225 days of pregnancy, showed a comparatively low cream volume of 28 and 12 per cent and rate of flow of 74 and 113 seconds, respectively. The colostrum from the Jersey heifer, 363A, on the other hand, which calved normally after 247 days gestation showed a colostral cream volume of 88 per cent and a rate of flow of 365 seconds.

From these studies of the effect of dry period and length of gestation upon the creaming and viscosity, the conclusion seems apparent that in order for the colostral properties to develop in the mammary secretion, there must be a certain amount of glandular inactivity preceding a normal parturition. Of further interest would be a study of the secretions of cows aborting while in regular lactation.

*Effect of Edematous Condition Upon Creaming and Viscosity.* After noting that the colostral properties of creaming and viscosity can be influenced by certain conditions, effort was made to determine the influence of the condition of the udder upon these properties. Wise, et al. (48), made the observation that

Table 7. The effect of mammary edema upon colostral cream volume and rate of flow.

| Lactation | Amount of edema | No. cows | Cream volume (per cent) | Rate of flow (seconds) |
|---|---|---|---|---|
| First | none | 7 | 30 | 102 |
| | moderate | 29 | 71 | 717 |
| | extreme | 23 | 77 | 705 |
| Later | none | 30 | 68 | 447 |
| | moderate | 29 | 63 | 338 |
| | extreme | 5 | 56 | 423 |
| First & later | none | 37 | 61 | 381 |
| | moderate | 58 | 67 | 532 |
| | extreme | 28 | 70 | 650 |

colostrum tended to be more viscous from the more edematous udders. This view is borne out by data in Table 7 which illustrates a tendency for colostral cream volume as well as rate of flow to be influenced directly by the edematous condition of the udder. When tested by analysis of variance, however, the differences were found to be nonsignificant, the probability for cream volume was 0.50 and for rate of flow 0.19.

Effect of Mastitic Condition on Creaming and Viscosity. A common belief is that the cream volume in milk from mastitic udders is often more extensive than that from normal udders. To determine if in colostrum such was the case and if viscosity were similarly affected, the average value for these properties for cows with "B" and "C" ratings as described in Experimental Procedure were compared with the average for all cows studied and the results shown in Table 8. It was found that the cream volume in the colostrum from "C" cows was higher and from "B" cows lower than the average of all cows. The rate of flow was in both cases lower than the overall average. Any significance in these differences was offset by the extreme variability within each group. A t-test showed the probability of the comparison in cream volume to be approximately 0.19. The differences in the rate of flow were not large enough to warrant the application of the test.

Table 8. The effect of mastitis upon colostral cream volume and rate of flow.

| Mastitic classification | No. cows | Cream volume (per cent) | Rate of flow (seconds) |
|---|---|---|---|
| "C" | 16 | 74 | 391 |
| "B" | 13 | 59 | 398 |
| All cows | 125 | 66 | 514 |

Effect of the Quantity Secreted Upon Creaming and Viscosity. Eckles and Shaw (12) gave the quantity of secretion as one of the factors affecting the composition of milk. Effort was made in this experiment to determine if the same principle applied also in colostrum. How the cream volume and rate of flow of colostrum was affected by the quantity secreted is demonstrated for the Jersey breed in Fig. 4. Scatter diagrams constructed for the other breeds showed similar results. The linear correlation was calculated to determine the significance of this relationship, the results of which are presented in Table 9. The relationship between these properties was negative and because of wide variability between individual samples, the product-moment coefficients of linear correlation were not significant. This variability in the colostrum was especially noted when the amount secreted was below 15 pounds. Above this amount there was more reliability in expecting a lowered cream volume and rate of flow in the colostrum with an increase in secretion. In general,

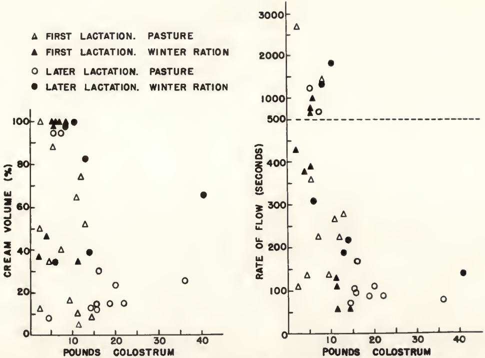


FIG. 4. EFFECT OF QUANTITY OF COLOSTRUM SECRETED UPON CREAM VOLUME AND RATE OF FLOW IN JERSEY COWS.

Table 9. Product-moment coefficients of linear correlation existing between the cream volume and rate of flow and the amount of colostrum secreted.

| Breed | No. cows | Cream volume vs. quantity | Rate of flow vs. quantity |
|---|---|---|---|
| | | r | r |
| Holstein | 36 | -0.423** | -0.322* |
| Ayrshire | 28 | -0.045 | -0.339 |
| Jersey | 38 | -0.169 | -0.331* |
| Guernsey | 20 | -0.382 | -0.338 |

** significant at 1 per cent level.
* significant at 5 per cent level.

however, it can be concluded that in colostrum as in normal milk the concentration of the product decreases with an increase in secretion.

## Relation of Certain Physical and Chemical Factors to Cream Volume and Viscosity of Colostrum

Many analyses of colostrum have been made in an attempt to learn the nature of this secretion. The results obtained from this study were essentially the same as those of other investigators as reported in the literature. Colostrum was found to differ from normal milk primarily in its variability and in the concentration of various constituents, particularly the globulin fraction. The measurements of creaming and viscosity were two easily determined methods that were tested and found indicative of the presence and amount of a number of colostral properties in a secretion.

Relation of Creaming and Viscosity. Before determining the extent to which certain physical and chemical properties of colostrum are indicated by means of the cream volume and rate of flow, the relationship existing between these two factors was studied. Figures 5 and 6 illustrate this relationship, while Table 10 shows the product-moment coefficients of linear correlation, according to breed and lactation, existing between these two properties.

These figures display a rather typical pattern characterized by an increasing variability in viscosity corresponding to the increased cream volume. The opposite tendency was found with regard to the viscosity; the higher it became the less variable the creaming. When the cream volume was below 90 per cent there was ordinarily a variability in rate of flow from 53 to 300 seconds. When the cream volume was 90 per cent or more, however, the variability in the rate of flow ranged from 160 to 4410 seconds. Another way of expressing this relationship is that in colostrum with a rate of flow less than 520 seconds the cream volume might range from 3 to 100 per cent. However, when the rate of flow was larger than this, there was no case wherein the cream volume was less than 95 per cent.

From Table 10 it is apparent that the relationship between colostral cream volume and rate of flow is variable, depending

Table 10. Product-moment coefficients of linear correlation existing between colostral cream volume and viscosity.

| Breed | Lactation | Number cows | r |
|---|---|---|---|
| Holstein | first | 13 | 0.497 |
| | later | 22 | 0.728** |
| Ayrshire | first | 13 | 0.569* |
| | later | 15 | 0.322 |
| Jersey | first | 21 | 0.706** |
| | later | 16 | 0.819** |
| Guernsey | first | 10 | 0.702* |
| | later | 10 | 0.692* |

** significant at 1 per cent level.
* significant at 5 per cent level.

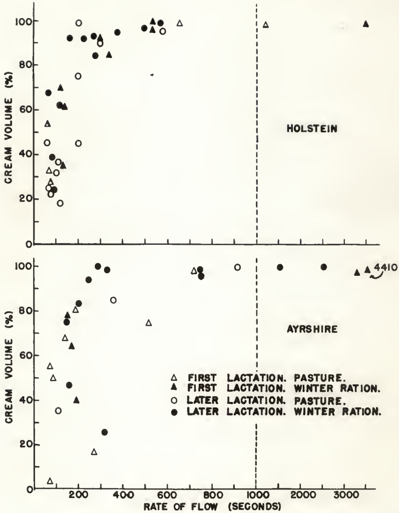


FIG. 5. RELATION OF CREAM VOLUME TO RATE OF FLOW IN COLOSTRUM FROM HOLSTEIN AND AYRSHIRE COWS.

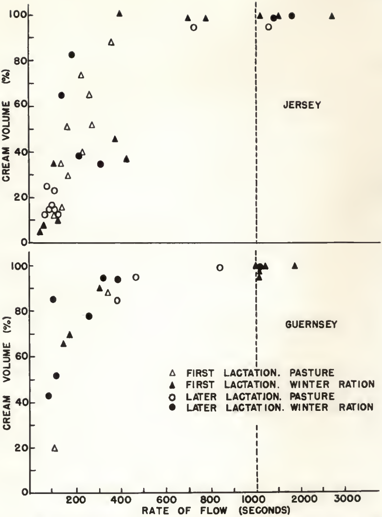


FIG. 6. RELATION OF CREAM VOLUME TO RATE OF FLOW IN COLOSTRUM FROM JERSEY AND GUERNSEY COWS.

somewhat upon the breed, lactation and possibly other factors. There was no consistent pattern to these variations. It was the Ayrshire cows in later lactations which had the lowest correlation while the cows of the Jersey breed in subsequent lactations had the highest correlation. From these data it may be concluded that factors which are related to creaming will likewise be related to viscosity. The validity of this relation is borne out in subsequent material. Also to be noted was the high degree of variability of these properties of creaming and viscosity; and the average values were much higher than those obtained in normal milk.

Relation of Specific Gravity to Creaming and Viscosity. The specific gravity in normal milk is recognized as being rather constant, varying but little from the average of 1.032. The specific gravity in colostrum on the other hand was much greater than that found in milk and was also extremely variable. The extent to which the colostral specific gravity was related to cream volume and rate of flow in the Jersey cows is shown in Fig. 7. That a significant correlation similarly existed, despite wide variability, in other breeds except the Holstein is demonstrated in Table 11. This variability was especially apparent when the specific gravity of the product was between 1.050 and 1.075. Colostrum with a lower specific gravity had a low cream volume and rate of flow while all cases over this level had a cream volume of over 85 per cent and a rate of flow of over 1000 seconds.

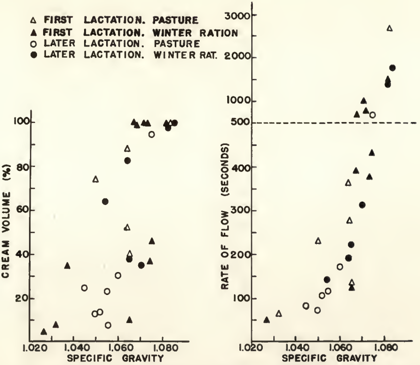


FIG. 7. RELATION OF SPECIFIC GRAVITY TO COLOSTRAL CREAM VOLUME AND RATE OF FLOW IN JERSEY COWS.

Table 11. Product-moment coefficients of linear correlation of specific gravity to cream volume and rate of flow of colostrum.

| Breed | Number cows | Cream volume | Rate of flow |
|---|---|---|---|
| | | r | r |
| Holstein | 27 | 0.299 | 0.349 |
| Ayrshire | 23 | 0.641** | 0.402* |
| Jersey | 28 | 0.660** | 0.641** |
| Guernsey | 19 | 0.833** | 0.715** |

** significant at 1 per cent level.
* significant at 5 per cent level.

Relation of Solids-not-fat to Creaming and Viscosity. With the discovery of such a significant correlation of the specific gravity to cream volume and rate of flow, it was deemed advisable to determine the extent to which this relationship was due to the solids-not-fat and to what extent to the fat present. When the product-moment coefficient of linear correlation between cream volume and the solids-not-fat was determined, it was found to be 0.720. With the rate of flow the linear correlation was 0.606. This relationship is further depicted in Fig. 8. The pattern here was very similar to that of the specific gravity. When the solids-not-fat content was between 12 and 22 per cent the cream volume was quite variable. Below this level the cream volume was less than 10 and above this level it was more than

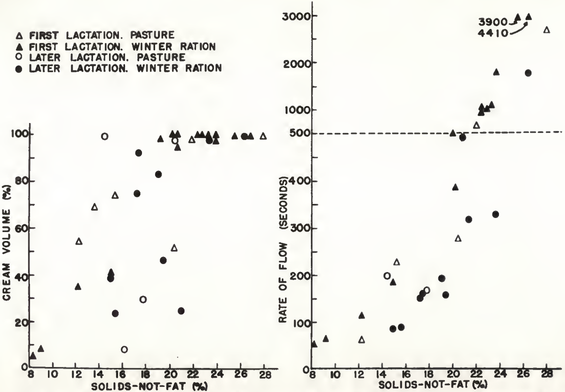


FIG. 8. RELATION OF SOLIDS-NOT-FAT TO CREAM VOLUME AND RATE OF FLOW IN COLOSTRU

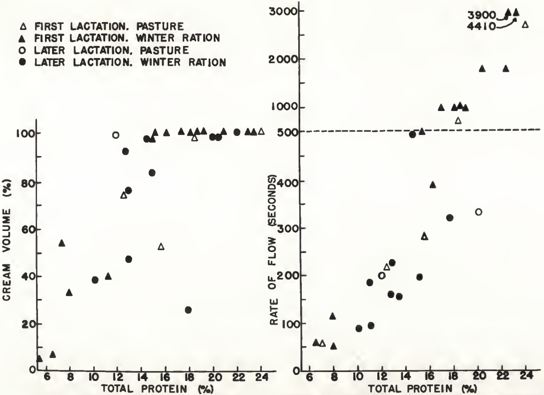


FIG. 9. RELATION OF TOTAL PROTEIN TO CREAM VOLUME AND RATE OF FLOW IN COLOSTRUM.

98 per cent. The picture presented by the rate of flow was very similar.

Relation of Proteins to Creaming and Viscosity. Since the proteins were found to be the most important solids-not-fat constituent quantitatively, Fig. 9, showing the relation of this factor in colostrum to the cream volume and rate of flow, is of special interest. It was found that with the exception of one normal, non-edematous Ayrshire cow, all samples with more than 16 per cent total protein had a cream volume of over 97 per cent. Below this protein level the cream volume was variable but tended to increase with an increase in protein content.

Below 350 seconds, the rate of flow showed a good linear relationship with the total proteins. Above this value, the reliability was decreased.

Despite the divergence in these values, the linear correlation of cream volume and rate of flow to the total protein content was found significantly high as shown in Table 12. In the cows studied, the relation of the cream volume and rate of flow to the albumin and globulin content differed greatly according to lactation. This difference is shown in Figs. 10 and 11 and in the linear correlation values shown in Table 12. The cream volume of the colostrum secreted by all first lactation heifers was unusually high, being more than 98 per cent, and the rate of flow with one exception was more than 500 seconds. The albumin and globulin content varied between 7 per cent and 16 per cent.

Table 12. Product-moment coefficients of linear correlation of proteins to cream volume and rate of flow of colostrum.

| Ration | Lactation | No. cows | Cream volume | Rate of flow |
|---|---|---|---|---|
| | | | r | r |
| Total Protein | | | | |
| Pasture | all | 6 | 0.533 | 0.887** |
| Winter | first | 14 | 0.879** | 0.707** |
| | later | 10 | 0.572 | 0.761** |
| Albumin & Globulin | | | | |
| Winter | first | 10 | 0.089 | 0.029 |
| | later | 10 | 0.417 | 0.877** |

** significant at 1 per cent level.

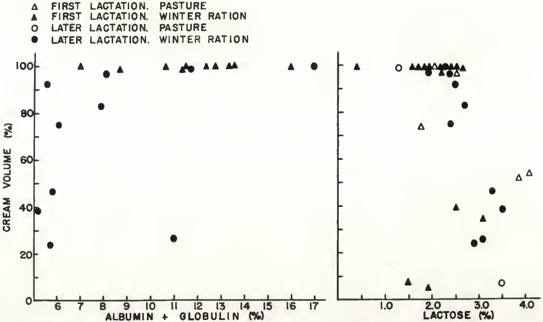


FIG. 10. RELATION OF ALBUMIN + GLOBULIN AND LACTOSE TO CREAM VOLUME IN COLOSTRUM.

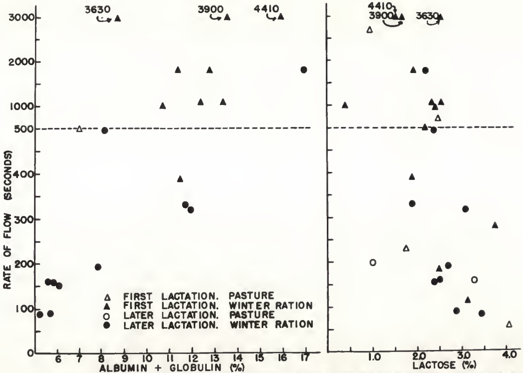


FIG. 11. RELATION OF ALBUMIN + GLOBULIN AND LACTOSE TO RATE OF FLOW IN COLOSTRUM.

The colostrum from later lactation cows showed a range in cream volume from 24 per cent to 92 per cent when the albumin and globulin content was five per cent to eight per cent. Above this albumin and globulin level the cream volume was over 95 per cent with one exception for which there was no apparent explanation other than the individual variability. The rate of flow in colostrum from the cows in later lactations was a relatively reliable estimation of the albumin and globulin content, bearing a direct relationship.

The casein content bore no apparent relation to either the cream volume or the rate of flow as indicated by scatter diagrams made to study this relationship. The presence of casein was reported as being somewhat greater in colostrum than normal milk but apparently has no measurable relation with the creaming and viscosity.

It appeared that of the solids-not-fat the albumin and globulin influenced colostral cream volume to the greatest extent. Especially was this noticeable when the albumin and globulin content was above 8 to 10 per cent. Apparently, below this level other factors caused the variation in the cream volume, whereas above this level there was enough albumin and globulin to either make the non-fat serum extremely small in proportion to the cream or prevent their separation entirely.

It was clearly evident that the albumin and globulin fraction of colostrum affected the viscosity. The relation of these factors was somewhat similar to that of cream volume except that there was no limit to the viscosity. Had there been a limit of 500 seconds for the rate of flow as there was of 100 per cent with creaming, the two relationships would have been very much alike.

In these analyses colostrum from the mammary glands functioning for the first time generally had a higher albumin and globulin content than that from udders secreting for the second time. This fact is believed to be responsible for the higher cream volume and viscosity observed in the colostrum from the heifers lactating for the first time. The only explanation at present is that these proteins are left as by-products of the growth and development necessary to initiate lactation. Since these cows were all on a winter ration, of further interest would be a study of the protein content of colostrum from cows on pasture and calving in different seasons of the year, in order to determine if these factors influenced the proteins and if a disturbance of the protein content were responsible for the differences in cream volume and viscosity noted under these conditions.

The possibility is suggested that the higher albumin and globulin content of colostrum might bear a relationship to the higher incidence and severity of mammary edema at calving time observed in heifers as compared to mature cows. Whether the edema is a result of the high albumin and globulin content of colostrum or visa verse is a provocative problem beyond the limits of this study.

Relation of Lactose to Creaming and Viscosity. Of the non-protein solids-not-fat there was a negative nonsignificant relationship existing between the lactose content and cream volume ($r = -.046$) and rate of flow ($r = -.093$). Taylor and Husband (44) suggested that the percentage lactose in milk controlled the daily volume secreted, the lactose content varying directly with quantity produced. Figures 11 and 12 show the relationship existing between the cream volume and rate of flow and the lactose present in colostrum. Contrary to the above suggestion, in colostrum there was a tendency for the creaming and viscosity to increase inversely with the lactose content.

Relation of Ash to Creaming and Viscosity. In preliminary studies, a scatter diagram was constructed to show the relationship between creaming and viscosity and the ash content. There was no indication of any relationship between these factors, although there was a greater variability in ash content noted in colostrum with 100 per cent cream volume than at any other creaming level.

Though the salt balance, electrolytes, and other factors present in the ash content may be essential for the expression of the phenomenon of creaming, there was no relationship between these two factors that could be noted from available facts.

The foregoing material would lead to the assumption that the solids-not-fat play an essential part in effecting the phenomena of creaming and viscosity of colostrum and the presence of solids-not-fat is indicated rather reliably by measurements of these properties.

Relation of Fat to Creaming and Viscosity. Quite customarily the fat content of milk is judged by the depth of cream layer formed. The results (Fig. 12) showed that within wide limits this was true, but the reliability decreased as the cream volume and fat percentage increased. Figures showing the product-moment coefficients of linear correlation between these two factors are presented in Table 13. The correlations were significant to a varying degree in all cases except in the values obtained from the Holstein heifers in their first lactation period.

The rate of flow was not a reliable index of the fat content in colostrum except in that from Holstein, Jersey and Guernsey heifers. Although the linear correlation in these cases was calculated as being highly significant, there existed as much as four per cent difference in the fat content at the same level of viscosity. The variability is further illustrated in Fig. 12 and Table 13. Attention is called to the fact that in each breed the colostrum from the first lactation showed a higher correlation than was to be found in the later lactations. Thus it may be noted that the fat content of colostrum is a relatively good index to creaming but is extremely variable in its relationship with the rate of flow.

Relation of Carotenoids, Vitamin A and Vitamin E to Creaming and Viscosity. Due to the nutritional importance of carotenoids, and vitamins A and E, it was of interest to determine their relationship to creaming and viscosity. The carotenoids present

Table 13. Product-moment coefficients of linear correlation of fat content to cream volume and rate of flow of colostrum.

| Breed | Lactation | No. cows | Cream volume | Rate of flow |
|---|---|---|---|---|
| | | | r | r |
| Holstein | first | 13 | 0.387 | 0.754** |
| | later | 22 | 0.456* | 0.009 |
| Ayrshire | first | 13 | 0.685** | 0.320 |
| | later | 15 | 0.785* | 0.264 |
| Jersey | first | 21 | 0.644** | 0.579** |
| | later | 16 | 0.776** | 0.168 |
| Guernsey | first | 10 | 0.740** | 0.738** |
| | later | 10 | 0.727** | 0.439 |

** significant at 1 per cent level.
* significant at 5 per cent level.

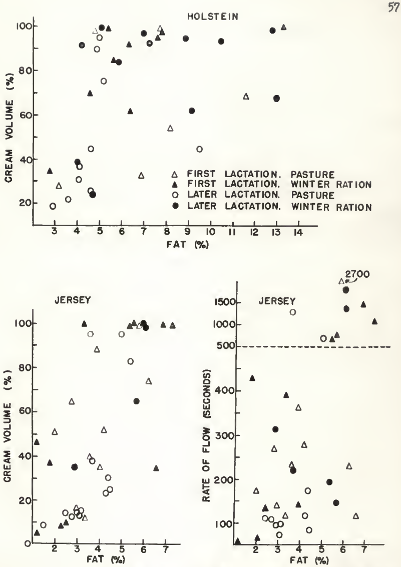


FIG. 12. RELATION OF FAT TO CREAM VOLUME AND RATE OF FLOW IN COLOSTRUM FROM HOLSTEIN AND JERSEY COWS.

in colostrum were generally higher and more variable in the colostrum from cows on pasture than that from cows on winter feed. Similarly, colostrum from cows receiving a vitamin A or vitamin E supplement displayed a generally higher and more variable vitamin content. This could be due in part to the greater variation in the intake, metabolism and secretion of these nutrients in the individual cows.

Since colostrum is generally described as being a yellow secretion believed to be rich in carotenoids, endeavor was made to determine whether the carotenoid potency would be indicated by the cream volume and rate of flow. By means of scatter diagrams it was shown that such a relationship did not exist. This fact was borne out further by statistical analyses.

The data showing the relationship between vitamin A and cream volume when translated onto a scatter diagram were demonstrated as being ill adapted for the determination of a linear correlation. The picture presented was one of increasing variability of vitamin A potency with an increasing cream volume. In cows not receiving a vitamin A supplement, at the 10 per cent cream volume level the vitamin A potency varied from 7 to 40 micrograms per 100 ml. colostrum. The 45 to 55 per cent cream volume level showed a vitamin A potency variation from 85 to 425 micrograms per 100 ml. colostrum, whereas at the 100 per cent level the potency varied from 100 to 650 micrograms per 100 ml. The colostrum from vitamin A supplemented cows showed a similar pattern at a higher level. This same tendency was shown in all breeds. Colostrum with a low cream volume could be expected to have a low vitamin A potency. However, with the rise in cream volume the reliability of predicting the vitamin A content decreased.

The rate of flow as a means of estimating the vitamin A potency of colostrum showed more dependable results for cows that received no vitamin A supplement. This was true in all except the Holstein breed regardless of lactation and ration. The linear correlation of Jersey cows was found to be 0.69. Since there was less variation observed in this breed than others, this calculation included also vitamin A supplement cows.

This relationship between vitamin A and the viscosity in colostrum is an extremely interesting one which strongly suggests that the vitamin A naturally occurring in colostrum (as from cows not receiving a vitamin A supplement) was related closely to the same factors responsible for the viscosity. The rate of flow appeared to be a dependable index of the vitamin A potency under these conditions, a high viscosity indicating a high vitamin A potency. Of interest is the observation that when the colostral vitamin A potency was increased by means of a concentrate in the prepartal ration of the cow, this relationship no longer existed.

The relation of the vitamin E potency to cream volume showed a scatter diagram pattern similar to that of vitamin A. From cows receiving no supplement, the vitamin E potency was between 100 to 300 micrograms per 100 ml. colostrum when the cream volume was below 10 per cent, but the range extended from 50 to 1100 micrograms when the cream volume was over 99 per cent. Colostrum from cows receiving a tocopherol supplement showed a similar relationship but at a higher level.

Although the above relationship existed between vitamin E and cream volume, no relationship of any type was apparent between vitamin E and viscosity.

These relationships have been determined on the basis of the micrograms carotenoids and vitamins A and E per 100 ml. colostrum. Since these are fat soluble materials, a more accurate picture probably could have been drawn by making use of the potency per gram of colostral butterfat.

Relation of Bloodiness to Creaming and Viscosity. It is not uncommon to observe a brown or red color in colostrum indicating the presence of blood. In order to determine the effect of blood upon the colostral cream volume and rate of flow, samples showing a pronounced bloodiness were compared with non-bloody samples from cows matched according to breed, lactation and ration. It was found that the bloody colostrum had a cream volume of 75 per cent and rate of flow of 562 seconds as compared to the non-bloody colostrum values of 85 per cent cream volume and 386 seconds rate of flow. When the t-test was applied to these differences it was found that they were both nonsignificant. The approximate probabilities were 0.25 for cream volume and 0.33 for the rate of flow. There were no cows of the Jersey breed that secreted bloody colostrum in the first milking. It is not possible from the limited data to determine whether there was a breed difference in the secretion of bloody colostrum or if it was a matter of coincidence that no Jersey cows were noted.

This information, though not conclusive, would indicate that the presence of blood has a depressing effect upon the cream volume and an increasing effect upon the viscosity. The apparent effect upon the creaming could possibly be explained by the presence of blood constituents which interfere with the creaming properties, whereas the greater viscosity might be due to the presence of the blood fibrin and corpuscles.

Relation of Leucocytes to Creaming and Viscosity. The investigators whose work was reviewed noted a high incidence of cellular material in colostrum. Since there was reportedly a direct relationship between large numbers of leucocytes and the cream volume, an attempt was made to find if the creaming together with viscosity in colostrum would indicate the number of these cells present. Microscopic examination was made on the colostral secretion of 13 cows of all four breeds receiving a winter ration. All with the exception of two heifers were in a later lactation. The number of leucocytes present was determined for the first, third and eighth milking. In the case of five cows, counts were also made on the second day.

With the exception of cows 363A and 355A, results showed the leucocyte count to be greatest in the first milking, decreasing coincident with cream volume and rate of flow with the transition to normal milk. In no case was the leucocyte count higher in the eighth milking of colostrum than in the first.

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The numbers varied greatly from ~~60,000,000~~ 6,000,000 to ~~1,820,000,000~~ 18,200,000 leucocytes per ml. in the first milking with the cream volume varying from 9 to 95 per cent and the rate of flow from 70 to 532 seconds. The samples representing extremes in leucocyte numbers, however, did not involve the same samples as those representing extremes in cream volume and viscosity.

These findings for the first and third milkings were plotted in a scatter diagram and the results of statistical treatment of the data showed that a linear correlation did not exist in either milking between the number of leucocytes present and the cream volume (r = 0.248 in the first milking and r = -0.380 in the third milking). The rate of flow showed a significant linear correlation of 0.612 in the first milking but in the third milking showed a nonsignificant correlation of -0.312. The fact that these relationships change from positive to negative from the first to third milkings, together with the low values obtained, indicated that the creaming and viscosity are of no value in estimating the leucocyte content in colostrum. These results were not in accord with the conclusion drawn from the literature reviewed prior to this study.

This study has demonstrated that colostrum is a highly variable product, the causes for which to a large extent remain unknown and have been attributed to peculiarities of the individual cow. The secretion of colostrum can be somewhat influenced by the prepartal ration and environmental temperature; however, the practicability of such a means of obtaining a secretion with high colostral properties is questioned.

Many colostral constituents can be estimated by measuring the creaming and viscosity, but the variability present causes such estimations, unless general in nature, to be unreliable. This study suggested that since colostrum with a high cream volume and viscosity contained a greater concentration of nutrients, it would be more desirable than normal milk in considering the physiological needs of the new-born calf.

As a single indication of the colostral properties of a secretion, there was not sufficient data to indicate the preference of creaming to viscosity or visa versa. Cream volume seemed to be indicative of a greater number of properties in the first milking, at least, but it was only the viscosity that reflected the slight decrease in the colostral properties such as proteins (50) after the eighth milking. Taken singly, both measurements can be used to indicate the colostral properties of a secretion, but a much more reliable index is available when both the cream volume and rate of flow are measured.

## SUMMARY AND CONCLUSIONS

It was recognized that an easily determined method of measuring the colostral properties of a mammary secretion would be desirable. Since the phenomena of creaming and viscosity appeared to be related to certain factors responsible for the unusual properties of colostrum, these phenomena were selected and studied in view of their relation to certain factors of production and other properties of colostrum.

In order to determine such relationships, environmental factors pertaining to the cow were noted. Samples representative of the complete colostral secretions from 123 cows of the Kansas State College purebred dairy herd of Holstein, Ayrshire, Jersey and Guernsey cattle were collected twice daily for the first four days and again on the seventh day postpartum. These samples were tested by a standard procedure for cream volume and rate of flow, a measurement of viscosity. For comparison with these two characteristics, analyses for other physical and chemical properties of colostrum were made.

The following conclusions were reached:

1. The relative colostral properties of a secretion can be determined by measurements of creaming and viscosity. Evidence leading to the preference of one measurement to the other was not conclusive. Taken singly, either measurement indicated some other colostral properties, but a more reliable index was available when both cream volume and rate of flow were measured.

2. The transition from colostrum to normal milk, as measured by creaming and viscosity, was most rapid during the first two days and had been completed after the fourth day postpartum with the exception of a few cases.

3. Colostrum was extremely variable in all analyses even when produced under the same experimental conditions.

4. The breed of cattle had no consistent influence upon colostral properties.

5. Colostrum from cows lactating for the first time showed characteristics that were significantly more pronounced than was noted in the colostrum from cows in later lactations. Among cows in later lactations (second to seventh) there was no appreciable difference in the characteristics of their colostral secretions.

6. The ration of the cow influenced colostral properties; the influence attributed to pasture was a decreased cream volume, which was statistically significant, and decreased viscosity, which was not statistically significant.

7. The effects which warmer seasons of the year and increased quantities secreted had upon colostrum were nonsignificant decreases in the colostral properties.

8. Apparently a mastitic condition tends to increase the creaming while decreasing the viscosity. Colostrum from edematous udders tended to be more viscous with no relation to creaming.

9. A certain amount of mammary inactivity together with a normal period of gestation was necessary apparently for the development of the extreme colostral properties that were noted. This was indicated by results obtained when one cow was milked continuously with no rest period and when two heifers calved prematurely.

10. A direct relationship was shown statistically to exist between both creaming and viscosity and the following colostral properties and constituents: specific gravity, solids-not-fat,

total proteins, albumin and globulin and fat content. A similar relationship seemed to be indicated between these two physical characteristics and vitamin A in the colostrum from cows not receiving a vitamin A supplement.

11. There was found to be an inverse relationship between creaming and viscosity and the lactose content. This relationship was found to be statistically nonsignificant, however.

12. No relationship was found between the creaming and viscosity and the casein, and ash, as these constituents remained relatively constant while creaming and viscosity varied widely; nor was a relationship found with the carotenoids, vitamin E, or leucocytes present. While these constituents were widely variable, they did not vary in relation to creaming and viscosity.

13. The presence of blood in colostrum tended to decrease cream volume and increase viscosity.

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